Transitioning the SWMF Geospace Model into Operations at the National Weather Service

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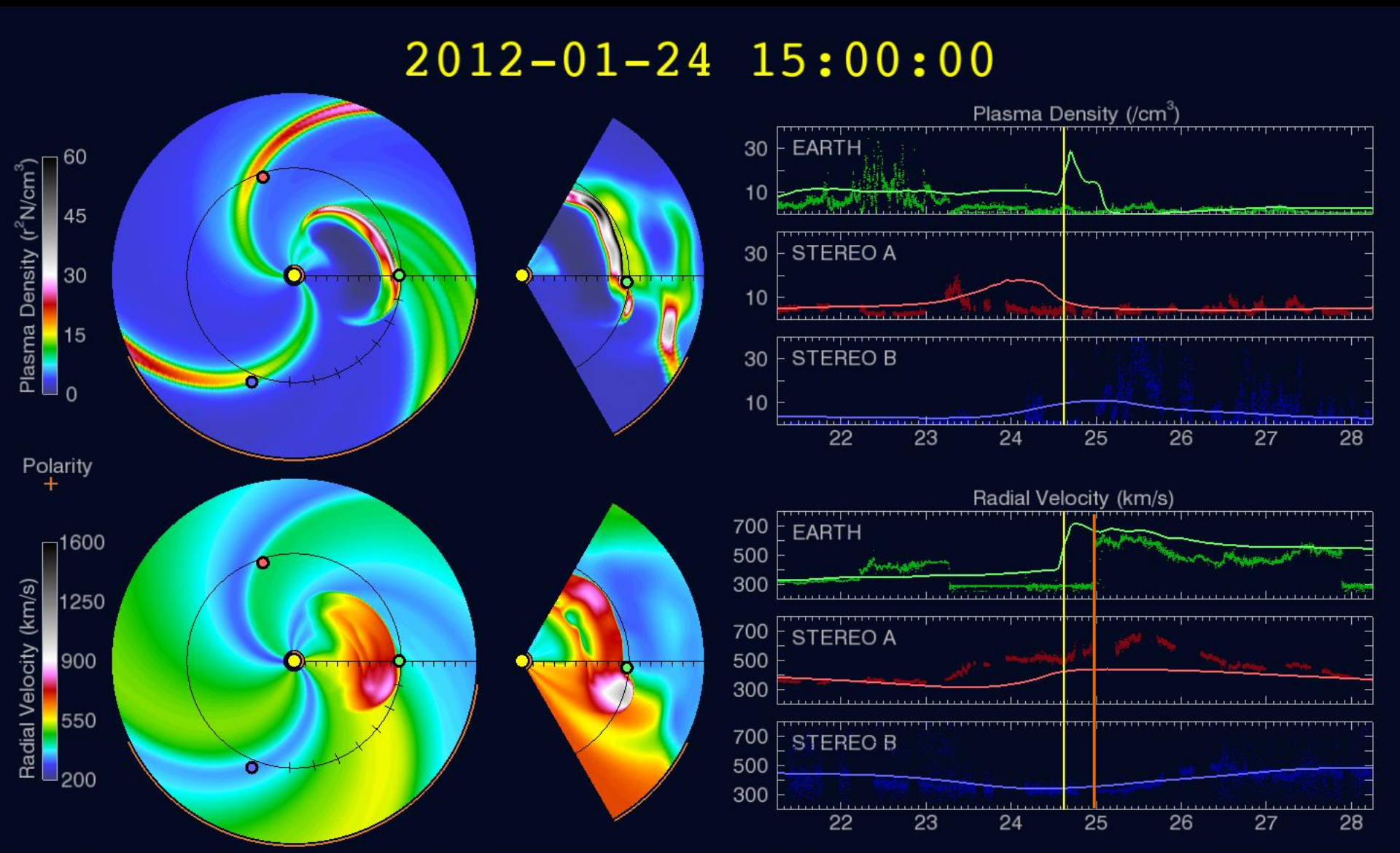
…and the Geospace evaluation team at CCMC

The National Centers for Environmental Prediction (NCEP) a part of the National Weather Service: "..the starting point for nearly all weather forecasts in the US"

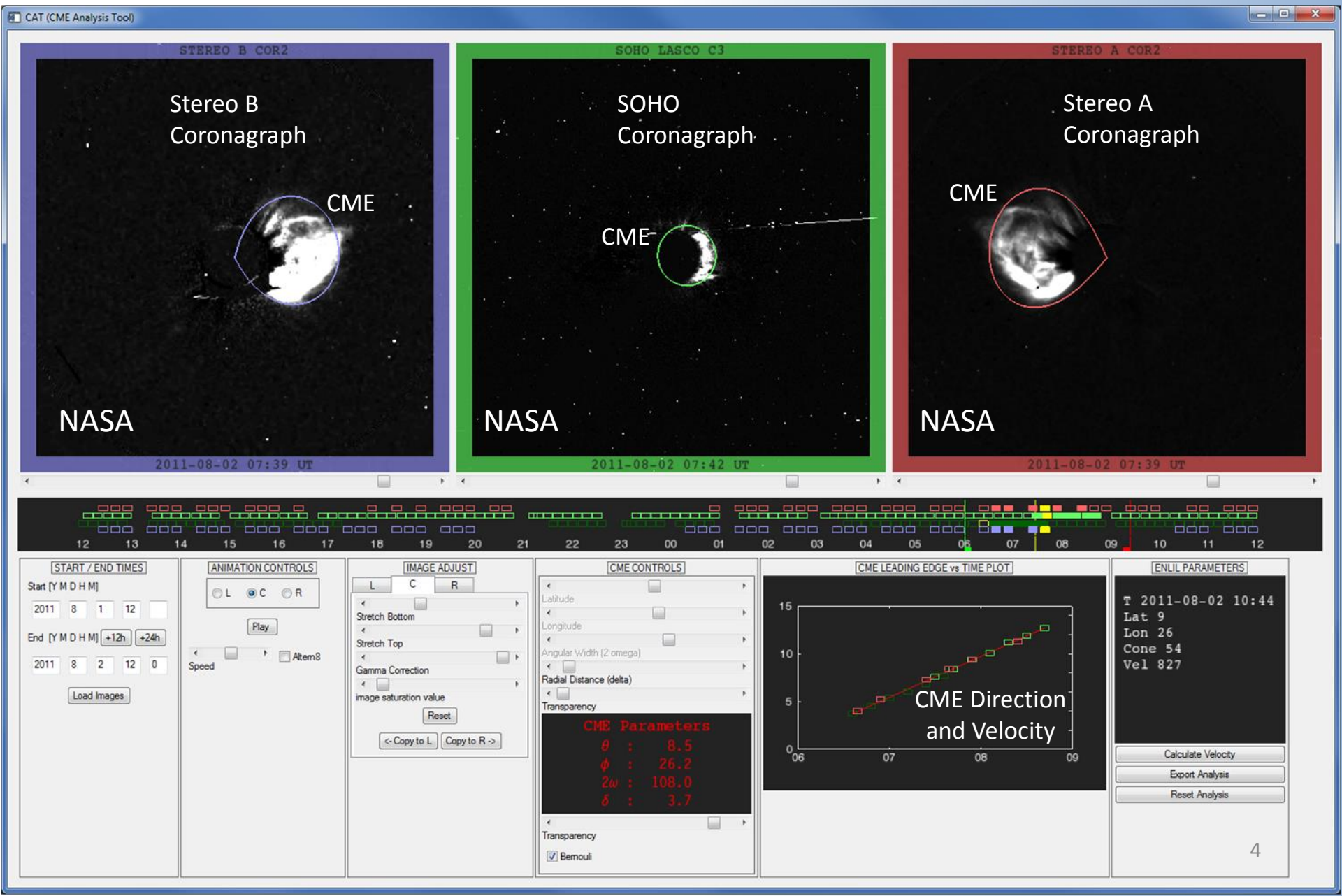
- Global Observations
- Operational computer modeling / Data Assimilation
- Post-Processing / Reforecasts

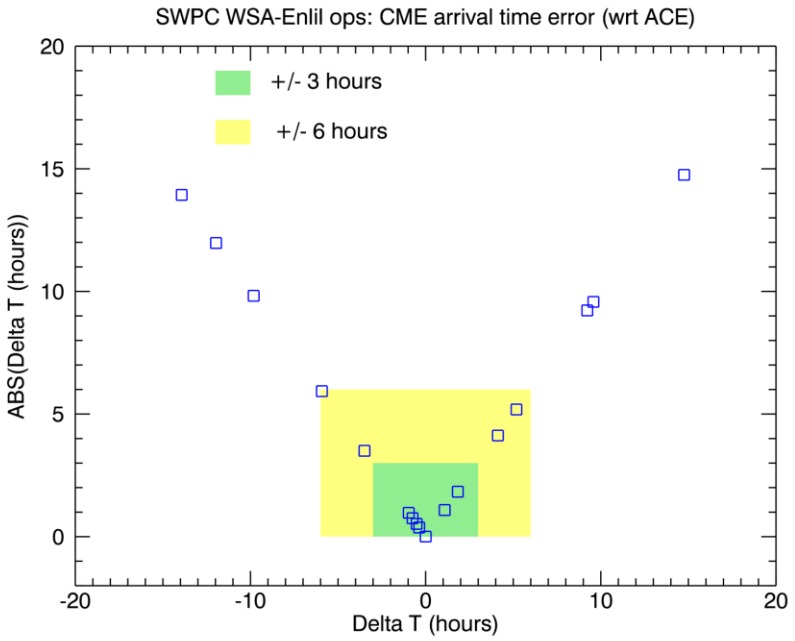
WSA-Enlil

- Transitioned by SWPC: 2010 - 2011
- Operational since 2012



CME Analysis Tool (CAT)





Mean error : +/- 7.5 hours

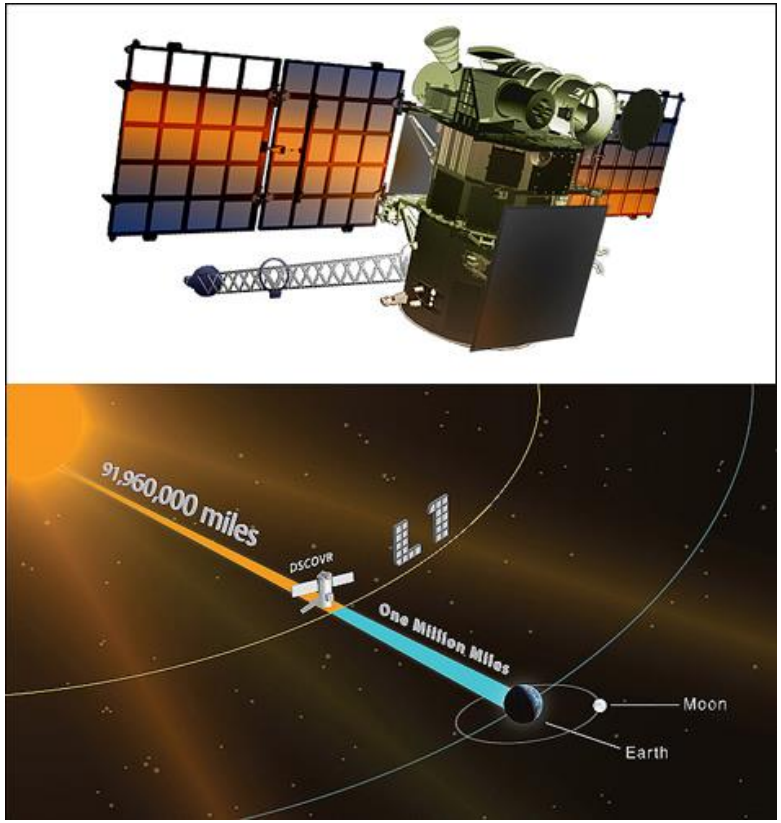
WSA-Enlil : invaluable forecasting tool at the 1 to 3 days level (18 hours)

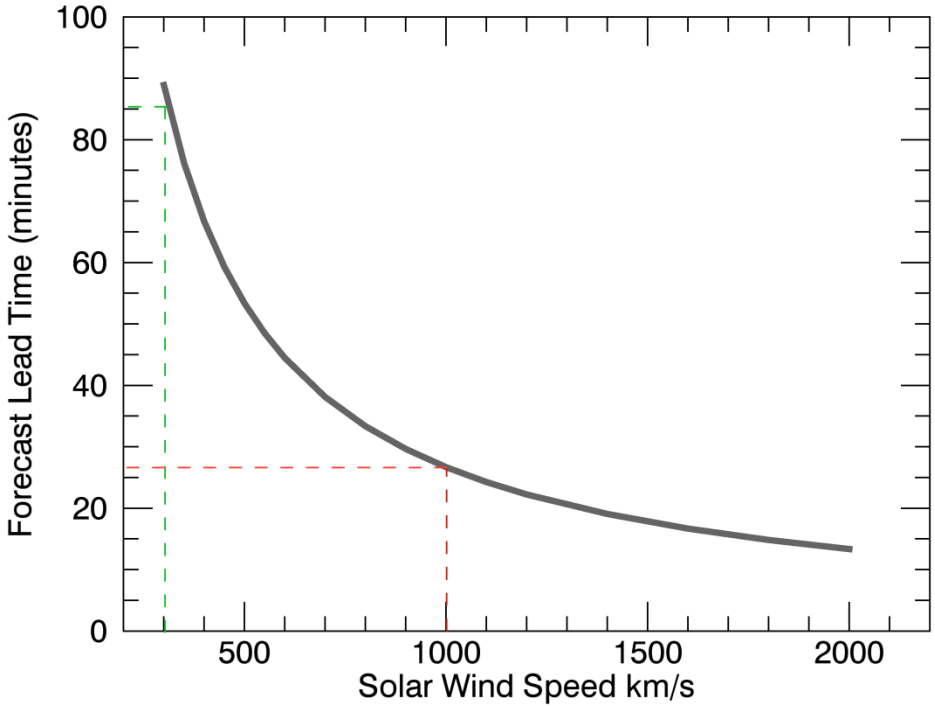
– but it can only get us so far:

- Inaccuracies in measured CME parameters (direction, velocity)
- No information about Geomagnetic storm severity – just possibility and CME time of arrival

In situ measurements, 92,000,000 miles further downstream….

ACE(1997) → DSCOVR(2015) :: Operational Sentinels at L1

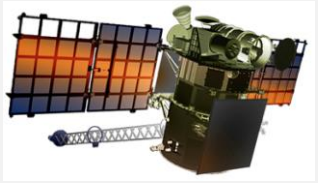


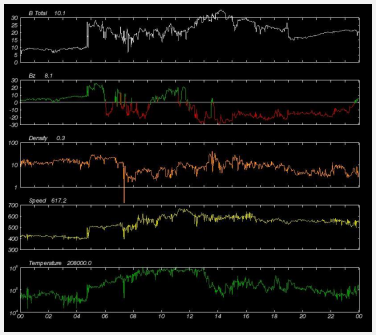


Fast incoming CMEs (say, >1000 km/s), Forecast lead time is less than 30 minutes

CURRENT CAPABILITY

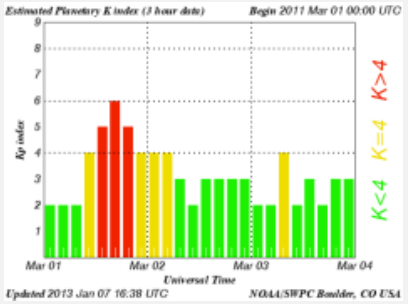
Satellite measurements of Solar Wind





Simple empirical relationships / neural networks etc.

Forecast of Geomagnetic activity: single value for the whole planet

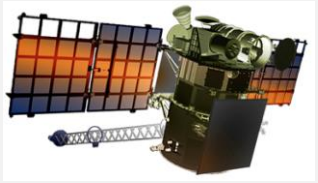


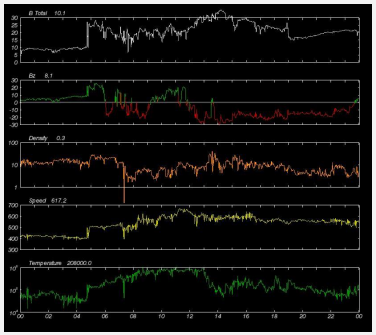
Global Forecast:

"In 18 minutes time the lights could go out – somewhere on planet Earth (probably at higher latitudes)"

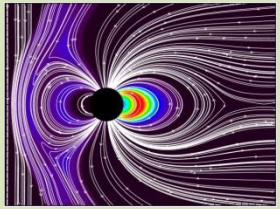
PROPOSED SYSTEM

Satellite measurements of Solar Wind

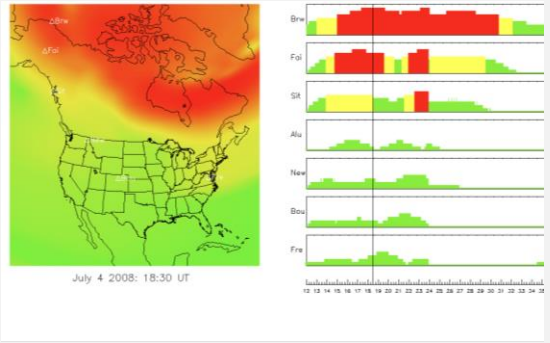




Sophisticated 3D model of Solar Wind-Magnetosphere running on WCOSS



Forecast of Geomagnetic activity as a global map



Regional Forecast:
"In 18 minutes time the lights could go out in New York, but not in Seattle, Tokyo, etc"
- focused, latitude, longitude, time.

Timeline to Operations……

- 2013: SWPC and NASA-CCMC - evaluation of suitable Magnetospheric models [in coordination with the modelers themselves]. Metrics: model skill scores for predicting dB/dt, regional K value, compared to 3 chains of magnetometers (east/West US and Europe). 6 magnetic storms evaluated.

- 2 reports prepared by CCMC (dB/dt | regional K)

- 2014: Space Weather Modeling Framework (SWMF), University of Michigan, chosen by SWPC as best performing – mature enough to provide significant advance in Geomagnetic forecasting.

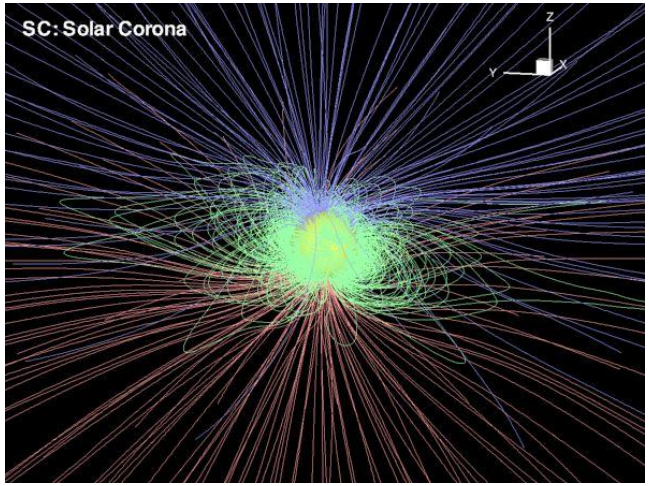
- 2014/2015: SWPC now working closely and extensively with model developers at UMICH to facilitate model changes needed for real-time operations.

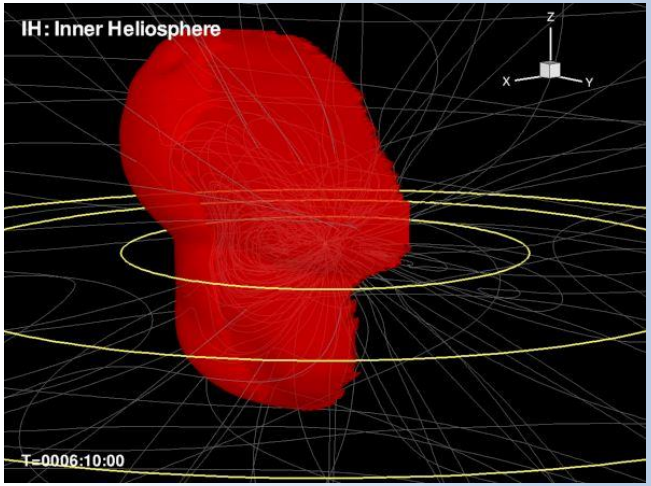
- Transition timeframe: Basic test-system running under DEV by Oct 1 2014 [done]….Full test system (v1.0) handed to NCO by October 1, 2015 for DEVONPROD.

- 2016: Operational (system v1.0)

Space Weather Modeling Framework SWMF:

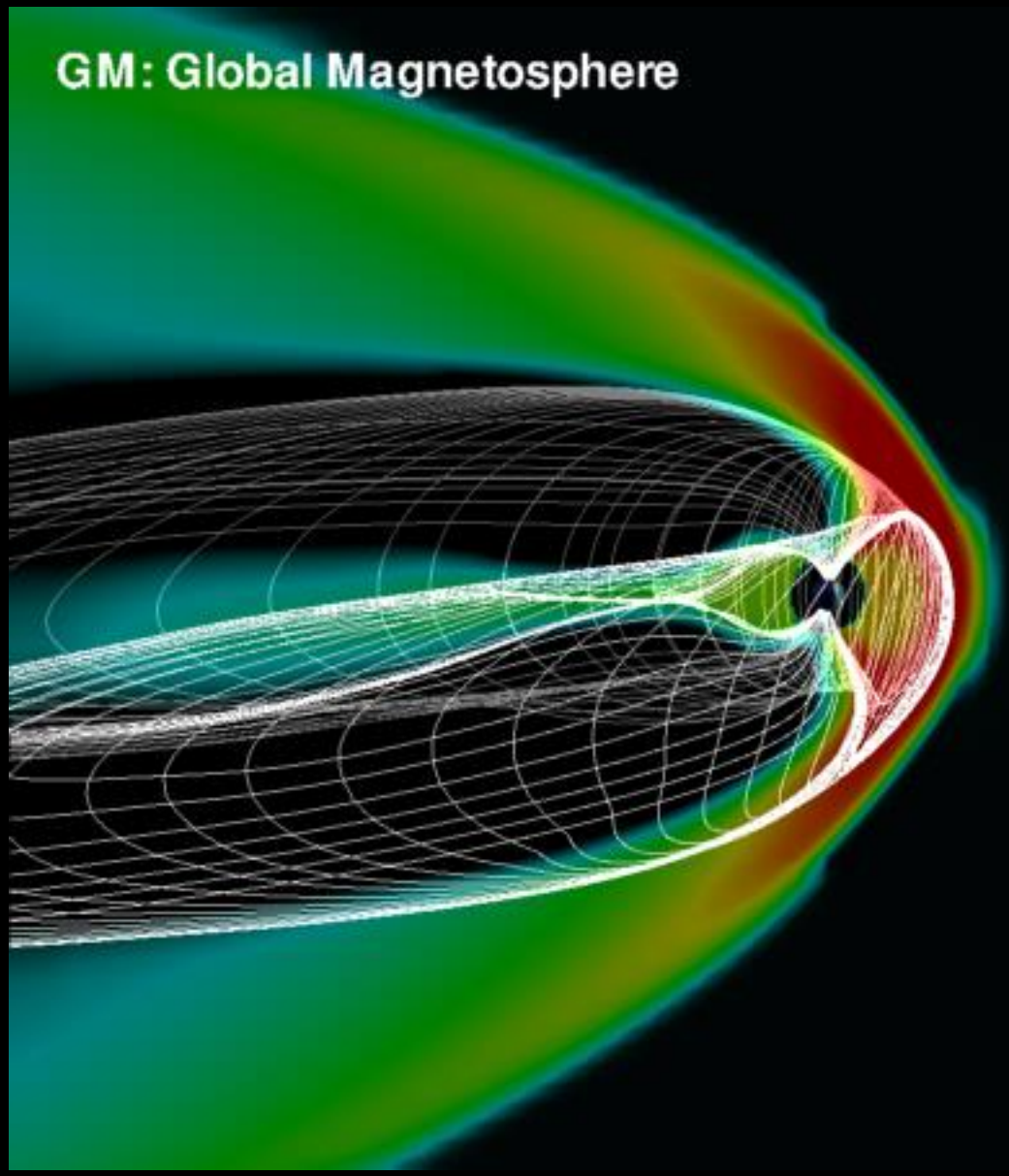
- Developed at the University of Michigan, Ann Arbor
- Comprehensive, 3D, time-dependent, physics-based, first principles model(s)
- Components can be combined together within the common “framework” (examples: Solar Corona, Inner Heliosphere)



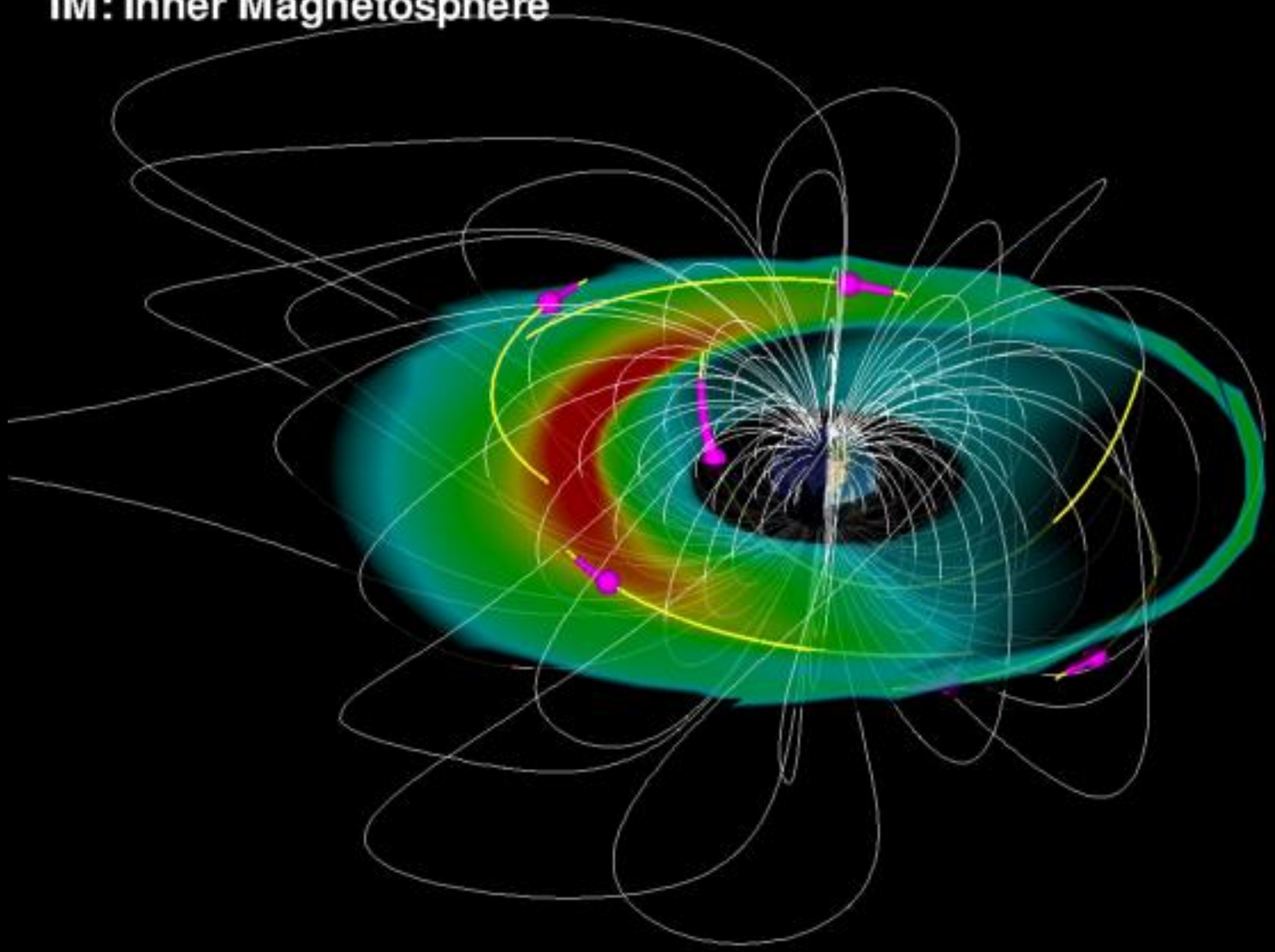


(essentially like the Enlil model)

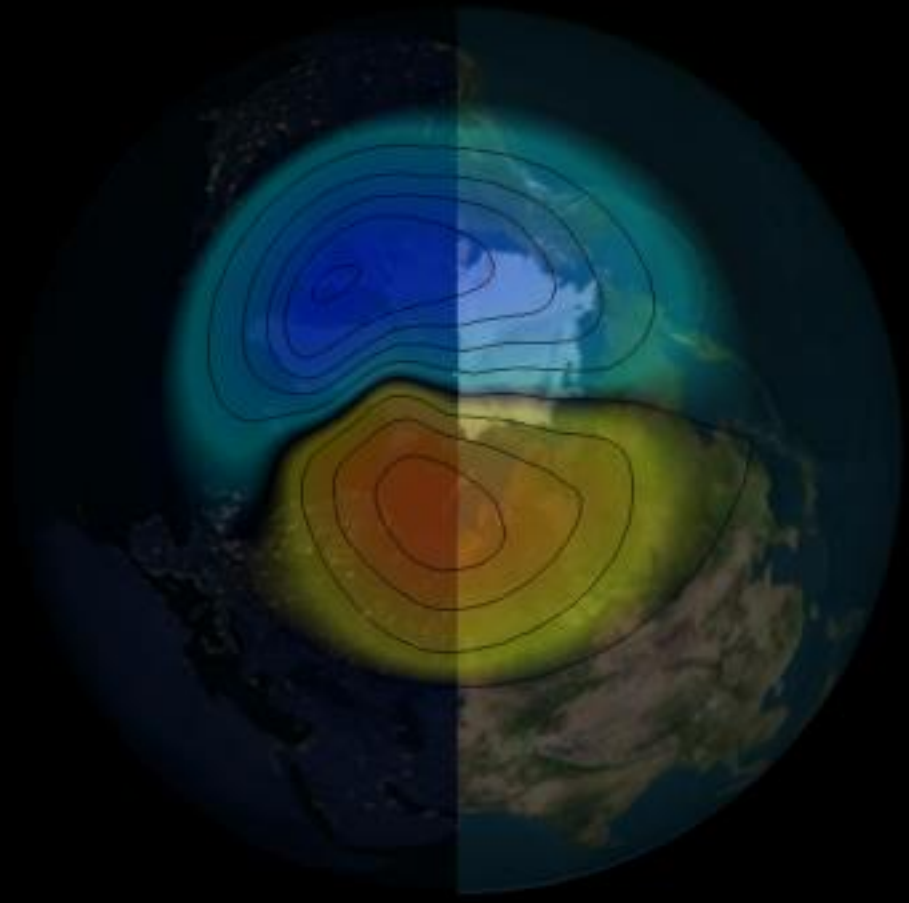
The components we are using for Geospace modeling……..

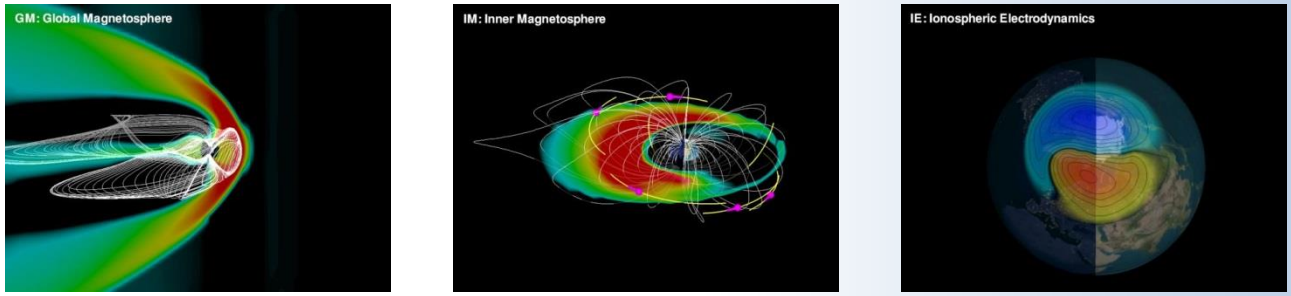

GM: Global Magnetosphere

IM: Inner Magnetosphere

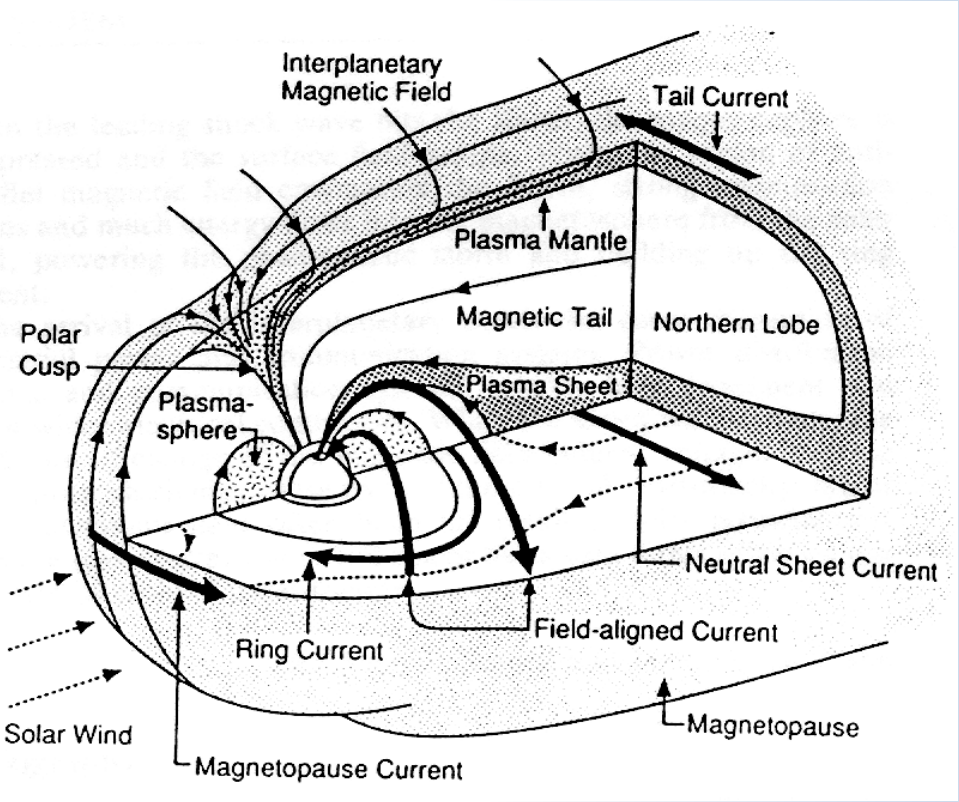


IE: Ionospheric Electrodynamics





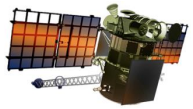
Several contributing current systems: Magnetopause, field-aligned, Ring Current, Ionospheric Pederson and Hall Currents:



Spatial and time-varying dB on the ground calculated via Biot-Savart integration.

Running a Geospace model as an operational forecast model : Essential Points :

- The magnetosphere is fundamentally a system driven by the Solar Wind
- The model does not “run into the future” (in a traditional weather model sense) – it just steps along in time with it’s Solar Wind input.
- Forecasting ability comes because the SW is measured 1 million miles upstream, at L1 – propagated forwards in time to the position of Earth



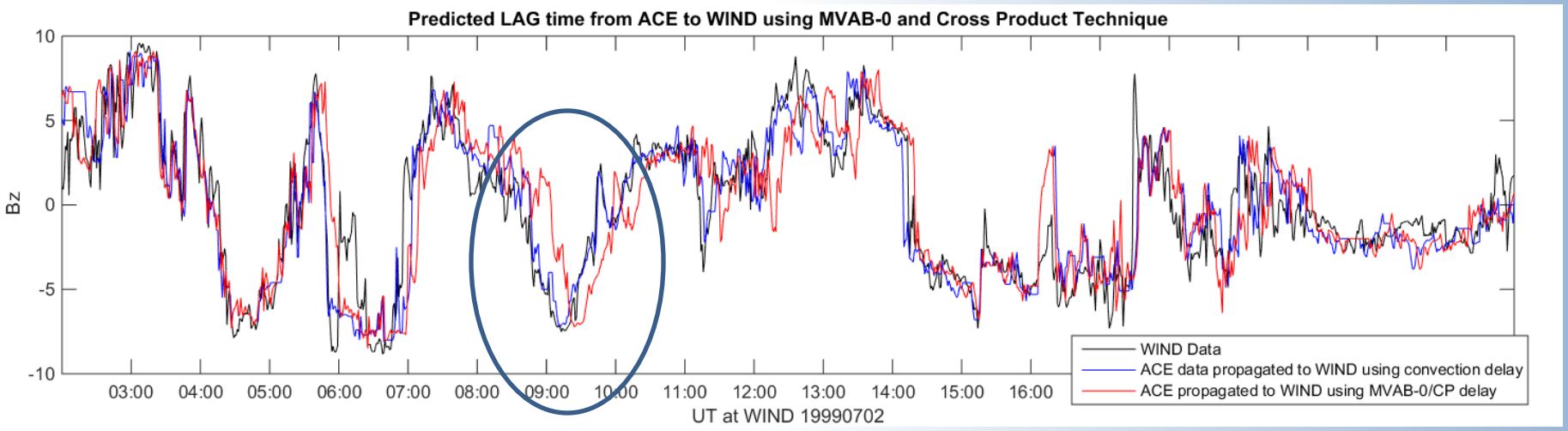
TIME TRAVEL at the SPEED of LIGHT

- Forecast lead time is dependent upon incoming SW speed
- Geospace model needs to run in Real-time (a paradigm shift for the NWS ops computer) – any computing delays will seriously eat into our 18 minutes.
- Sharp jump upwards in SW speed (ie, incoming CME) – model has to ***STOP and RESTART*** from a previous point consistent with the new SW data.

The TIME TRAVEL part

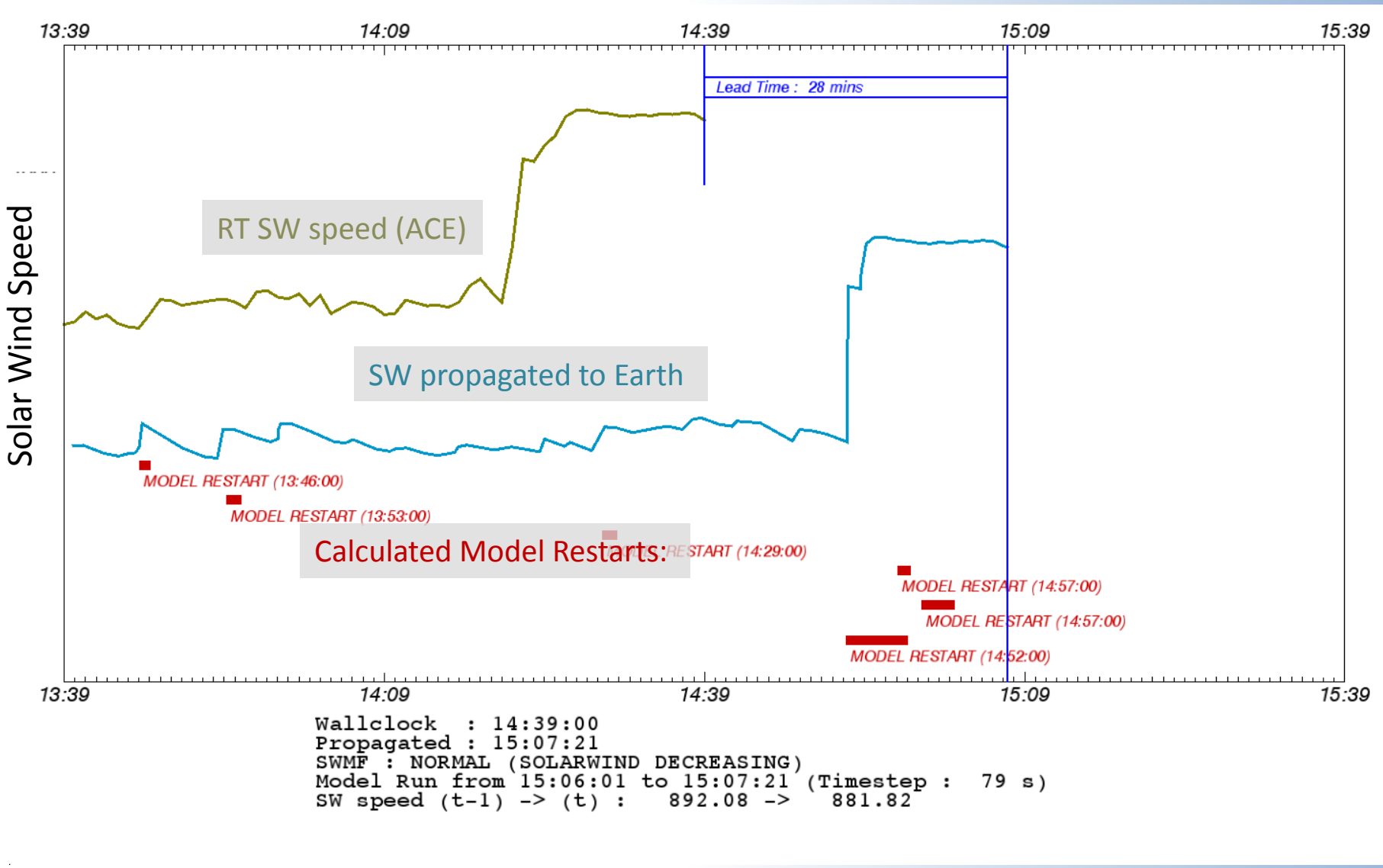
SW Transit Time: Validation (Michele Cash, SWPC)

ACE data propagated to the location of the Wind spacecraft using two different methods, flat plane propagation and tilted phase planes

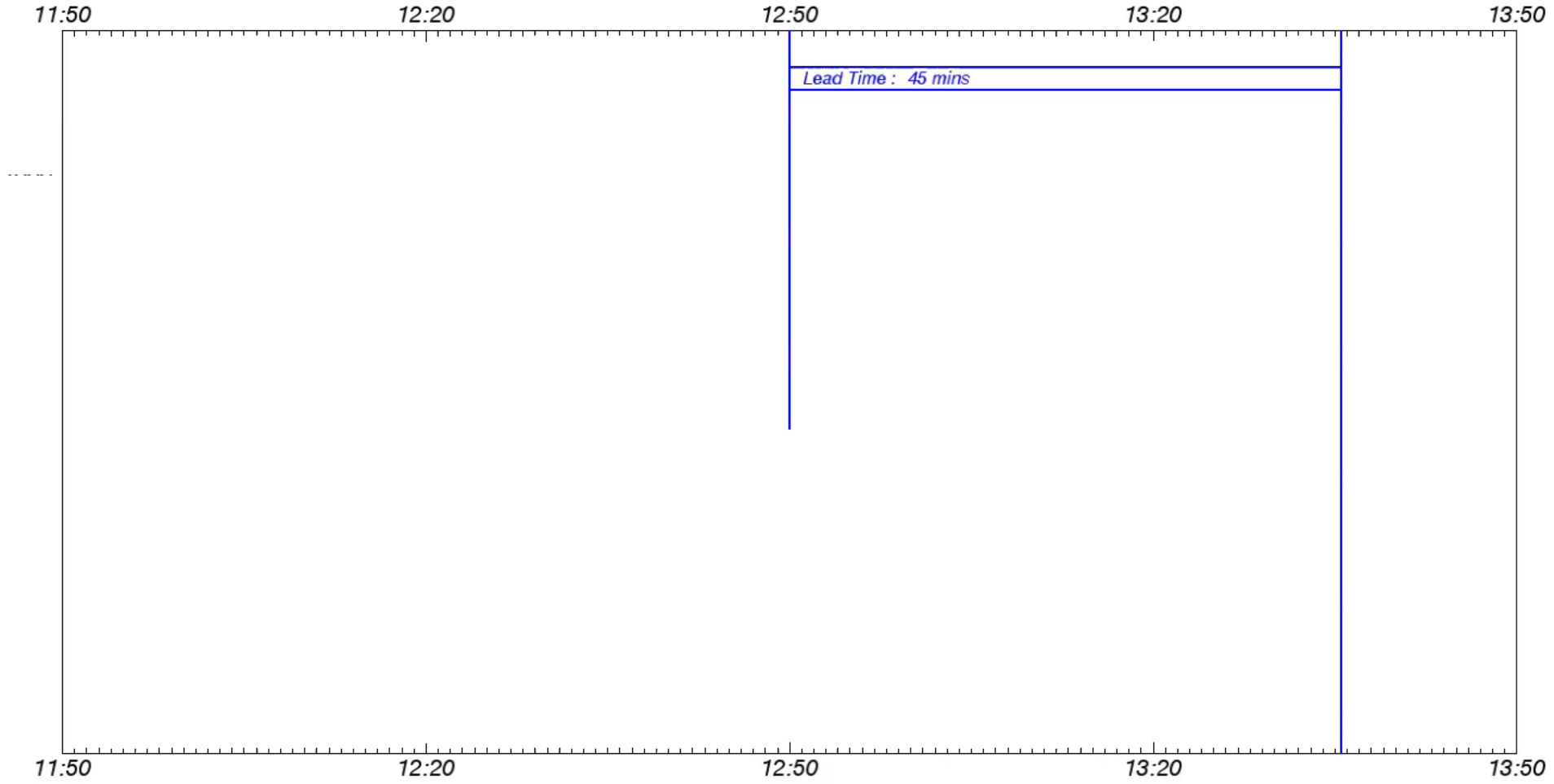


MVAB-0/CP method shows improved agreement

The *STOP and RESTART* part

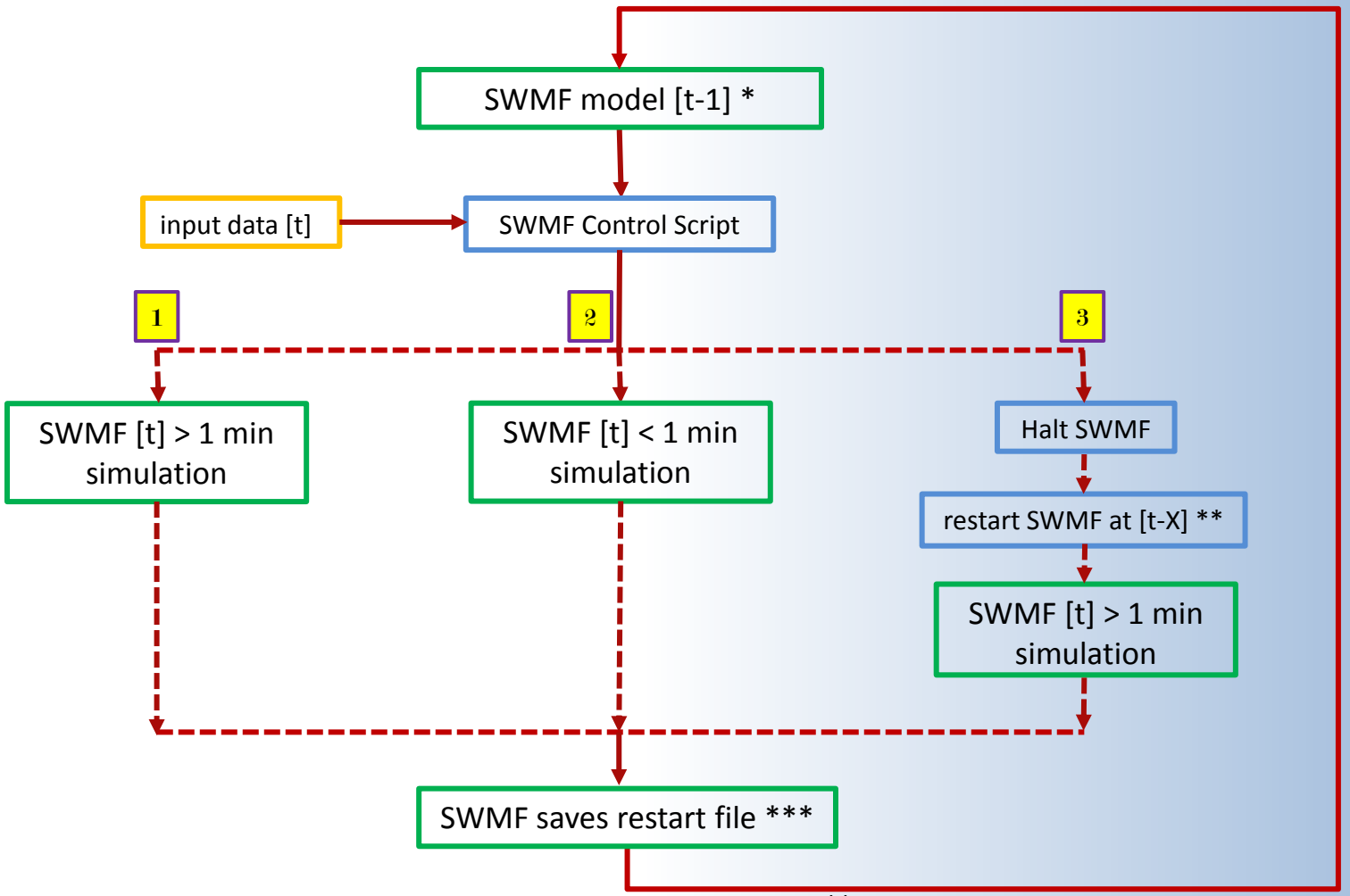


The *STOP and RESTART* part




```
Wallclock  : 12:50:00
Propagated : 13:35:27
SWMF : NORMAL (SOLARWIND INCREASING)
Model Run from  to 13:35:27 (Timestep :    0 s)
SW speed (t-1) -> (t) :     0.00 ->   549.94
```

Schematic for SWMF running in real-time on WCOSS: basic time stepping



1 V[t] < V[t-1] (solar wind decreasing)

2 V[t] > V[t-1] (solar wind increasing)

3 V[t] >> V[t-1] (sharp increase - shock)

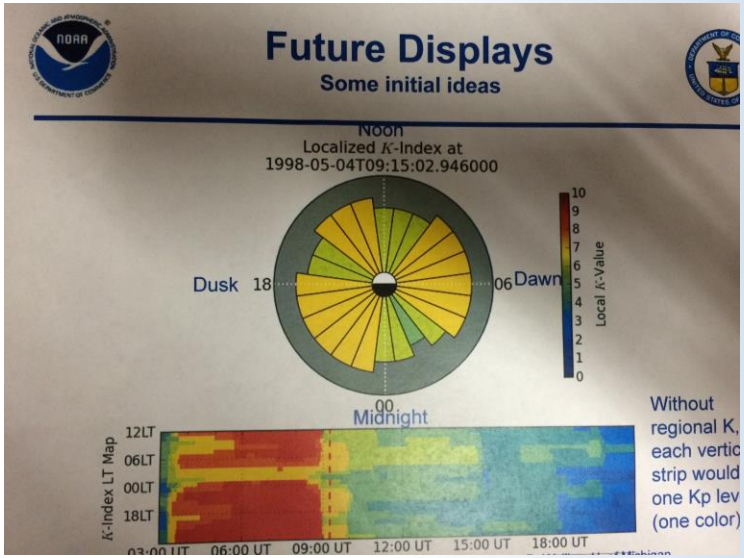
** WCOSS stores last 45 files before removing

* SWMF checks and waits for new input data

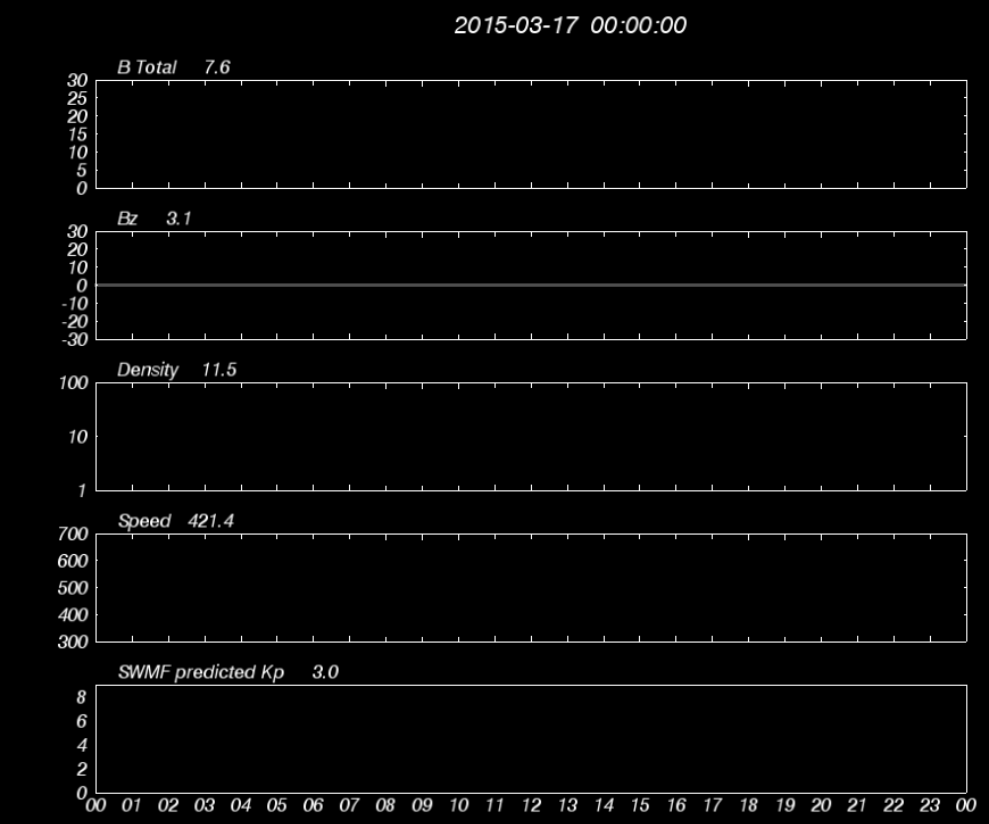
*** Restart file always saved on the minute

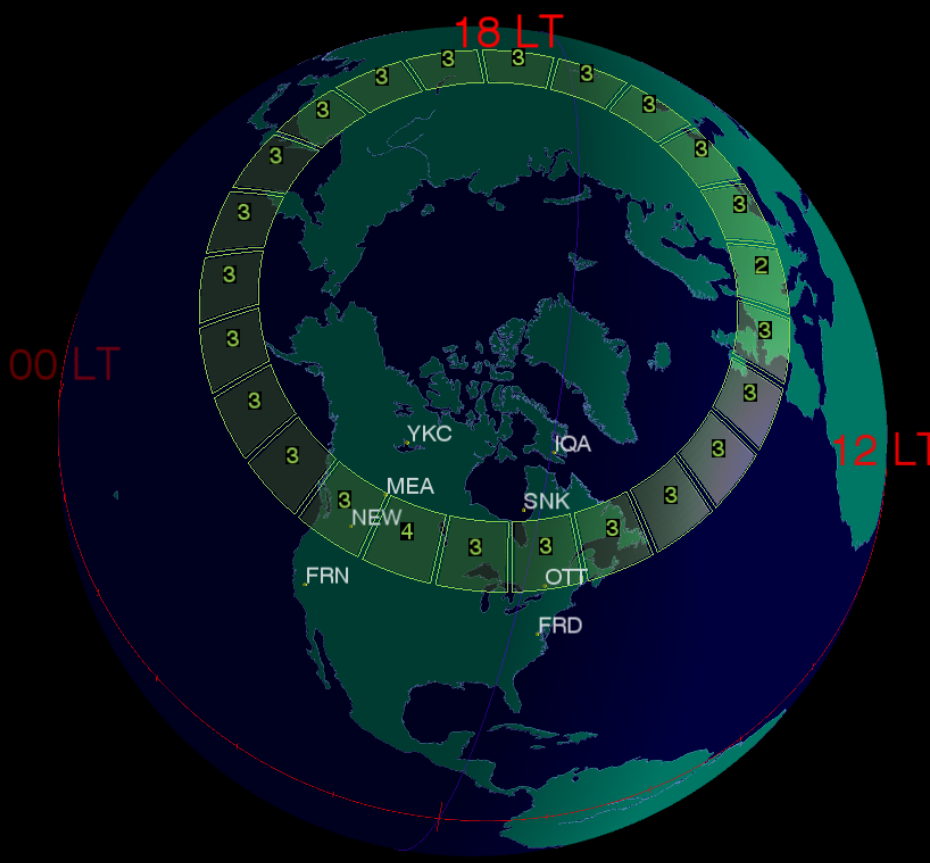
Forecast Products

- Initial products: Local Time regional K and dB/dt calculations at a few select locations
- More complete products and product displays to be developed in 2016
- Meanwhile - a suggestion from UMICH (Dan Welling) of a Local Time Regional K product shows interesting results (St Patrick's Day Storm)



Initial Test Product : Local Time regional K prediction

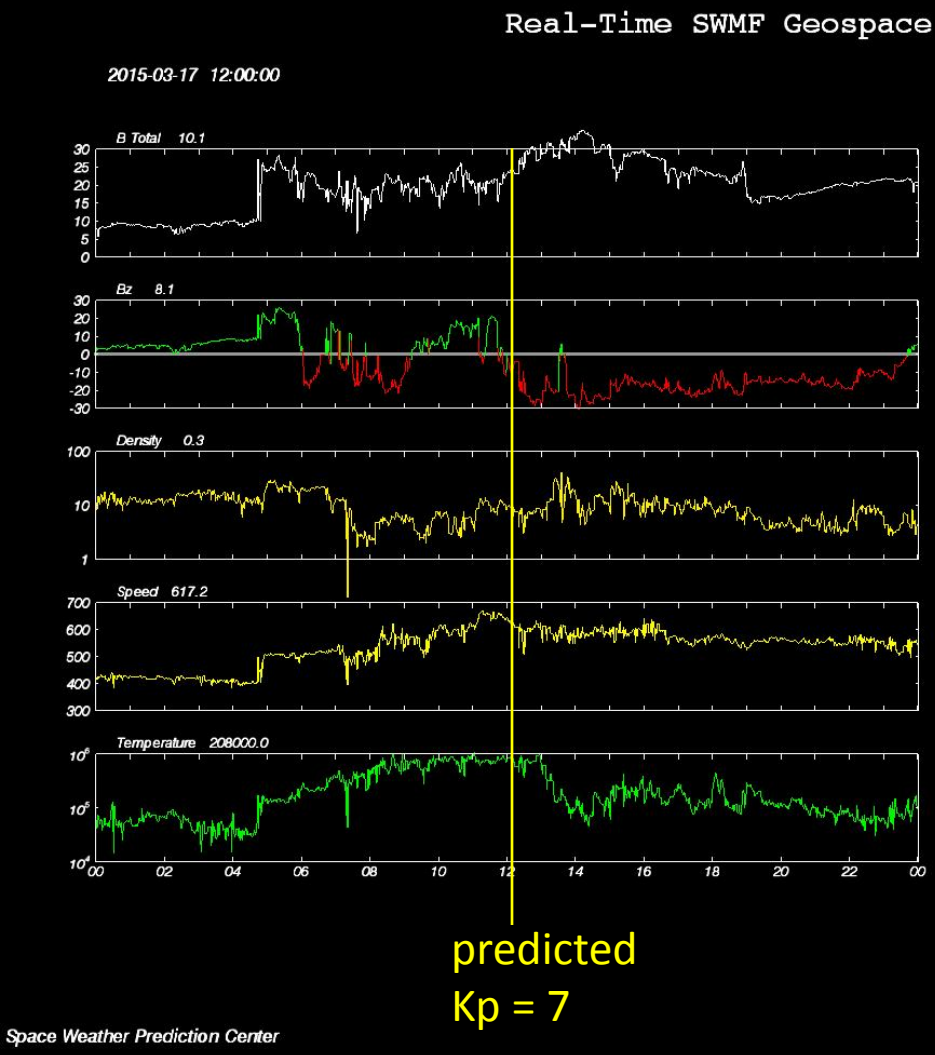


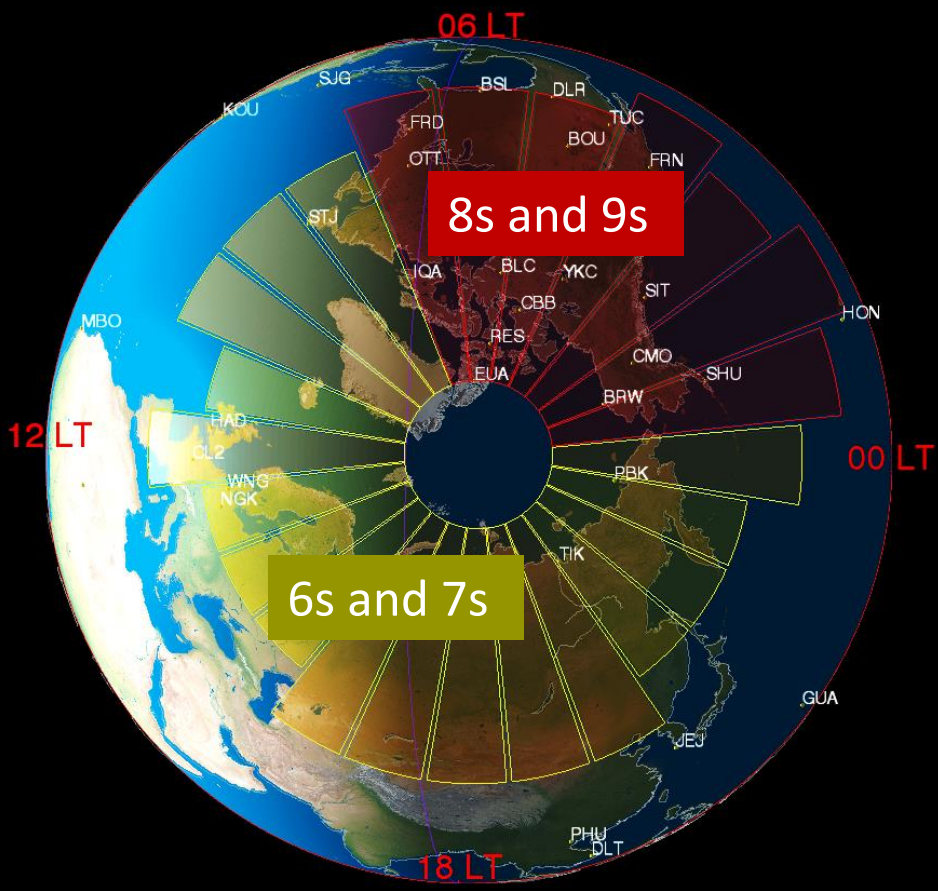


Space Weather Prediction Center

Initial Test Product : Local Time regional K prediction

Initial Test Product : Local Time regional K prediction





Summary

- Transition team at SWPC working in solid collaboration with model developers at UMICH to build a real-time operational Geospace model
- Real-time run environment in place on the DEV environment at NCEP : SWMF running in real-time with propagated SW data
- Initial forecast products show interesting, and very encouraging, results (St Patrick's day storm) – obviously lots more work to be done
- Handover to NCO techs slated for 1 October 2015 – V1.0 operational 2016

USERS: We will have [x,y,z,t] – 30 minutes ahead of time – what do you want ??? (global picture, local time series etc. etc.)

Get in the loop…. We have ideas – but we want yours…..

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